Prepared by
Oak Ridge Associated
Universities

Prepared for
Division of
Remedial Action
Projects

U.S. Department
of Energy

COMPREHENSIVE RADIOLOGICAL SURVEY

OFF-SITE PROPERTY W

NIAGARA FALLS STORAGE SITE

LEWISTON, NEW YORK

J. D. BERGER

Radiological Site Assessment Program
Manpower Education, Research, and Training Division

FINAL REPORT

February 1984

COMPREHENSIVE RADIOLOGICAL SURVEY

OFF-SITE PROPERTY W
NIAGARA FALLS STORAGE SITE
LEWISTON, NEW YORK

Prepared for

U.S. Department of Energy
as part of the
Formerly Utilized Sites -- Remedial Action Program

J.D. Berger

Project Staff

J. Burden*
R.D. Condra
J.S. Epler*
W.O. Helton
R.C. Gosslee
W.L. Smith*
T.J. Sowell
G.M. Stephens
L.B. Taus*
C.F. Weaver
B.S. Zacharek

Prepared by

Radiological Site Assessment Program
Manpower Education Research, and Training Division
Oak Ridge Associated Universities
Oak Ridge, Tennessee 37831-0117

FINAL REPORT

February 1984

This report is based on work performed under contract number DE-AC05-760R00033 with the Department of Energy.

*Evaluation Research Corporation, Oak Ridge, Tennessee

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

COMPREHENSIVE RADIOLOGICAL SURVEY

OFF-SITE PROPERTY W
NIAGARA FALLS STORAGE SITE
LEWISTON, NEW YORK

INTRODUCTION

Beginning in 1944, the Manhattan Engineer District and its successor, the Atomic Energy Commission (AEC), used portions of the Lake Ontario Ordnance Works (presently referred to as the Niagara Falls Storage Site (NFSS) and off-site properties), approximately 3 km northeast of Lewiston, NY, for storage of radioactive wastes. These were primarily residues from uranium processing operations; however, they also included: contaminated rubble and scrap from decommissioning activities, biological and miscellaneous wastes from the University of Rochester, and low-level fission-product waste from contaminated-liquid evaporators at the Knolls Atomic Power Laboratory (KAPL). Receipt of radioactive waste was discontinued in 1954, and, following cleanup activities by Hooker Chemical Co., 525 hectares of the original 612 hectare site were declared surplus. This property was eventually sold by the General Services Administration to various private, commercial, and governmental agencies.[1]

SCA Chemical Services, Inc., (SCA) is the current owner of a tract identified as off-site property W (see Figure 1). A radiological survey of that tract, conducted in July 1983, is the subject of this report.

SITE DESCRIPTION

General

Figure 2 is a plot plan of off-site property W. The property is roughly triangular in shape and occupies approximately 1.3 hectares. "M" Street is the southern boundary; a chain link security fence forms the property boundary along the northwest perimeter. The property is presently unused, overgrown with brush and trees, and contains no structures. The West Drainage Ditch

passes in a generally north/south direction through the eastern section of the property.

Radiological History

There is no evidence of storage or burial of contaminated material on property W. Runoff from storage areas on the Department of Energy site previously entered the West Drainage Ditch, contaminating sediments in the bed of the ditch. Dredgings from the ditch have been deposited along the east bank. Previous surveys have indicated elevated radiation levels along the ditch and its banks.[2-4]

SURVEY PROCEDURES

The comprehensive survey of NFSS off-site property W was performed by the Radiological Site Assessment Program of Oak Ridge Associated Universities (ORAU) during July 18-29, 1983. The survey was in accordance with a plan dated March 18, 1983, and approved by the Department of Energy. The objective and procedures from that plan are presented in this section. Decontamination and resurvey of the West Drainage Ditch is the responsibility of Bechtel National, Inc.; that ditch was therefore excluded from ORAU survey activities.

Objective

The objective of the survey was to provide a comprehensive assessment of the radiological on property W. Radiological information collected included:

1. direct radiation exposure rates and surface beta-gamma dose rates,
2. locations of elevated surface residues,
3. concentrations of radionuclides in surface and subsurface soil, and
4. concentrations of radionuclides in ground water.

Procedures

1. Site Preparation

   a. Brush and weeds were cleared as needed to provide access for gridding and surveying. This operation was performed under subcontract by Modern Disposal Co., Model City, NY.

   b. A 40 m grid system was established by McIntosh and McIntosh of Lockport, NY, under subcontract. This grid system is shown on Figure 3.

2. Gamma exposure rate measurements were made at the surface and at 1 m above the surface at each 40 m grid interval. Measurements were performed using portable gamma NaI(Tl) scintillation survey meters. Conversion of these measurements to exposure rates in microroentgens per hour (μR/h) was in accordance with cross calibration with a pressurized ionization chamber.

3. Beta-gamma dose rate measurements were performed 1 cm above the surface at each 40 m grid interval. These measurements were conducted using thin-window ($<7 mg/cm^2$) G-M detectors and portable scaler/ratemeters. Measurements were also obtained with the detector shielded to evaluate contributions of non-penetrating beta and low-energy photon radiations. Meter readings were converted to dose-rate in microrads per hour (μrad/h), based on cross calibration with a thin-window ionization chamber.

4. Surface (0-15 cm) soil samples of approximately 1 kg each were collected at or near each 40 m grid interval.

5. Walkover surface scans were conducted over all accessible areas of the property. Scanning intervals were 1-2 m along roads and ditch banks and 2-5 m on other property areas. Portable gamma scintillation survey meters were used for these scans. Locations of elevated contact radiation levels were noted and surface exposure rates were measured at these locations.

6. At selected locations of elevated surface radiation levels, beta-gamma dose rates and exposure rates at 1 m above the surface were also measured. Surface soil samples were obtained from these locations and, following sampling, the surface exposure levels were remeasured to evaluate the effectiveness of shallow sampling on removal of the radiation source. The locations where these additional measurements and samples were obtained are indicated on Figure 4.

7. Detection Sciences Group of Carlisle, MA, performed ground penetrating radar scans at locations of proposed subsurface investigations. The purpose of these radar scans was to identify the presence of underground piping or utilities which would preclude borehole drilling.

8. Boreholes were drilled to provide a mechanism for logging subsurface direct radiation profiles and collecting subsurface soil and water samples. Seven boreholes to ground water depth (3.5-6 m) and one shallow (to 1.5 m) borehole were drilled by Site Engineers, Inc., of Cherry Hill, NJ, using a truck-mounted 20 cm diameter hollow-stem auger. Five of the deeper boreholes were drilled at locations considered to be representative of average property conditions. The other two deep boreholes and the one shallow borehole were at locations where direct radiation levels had indicated contaminated residues. Locations of these boreholes are shown on Figure 5.

A gamma scan of each borehole was performed to identify elevated radiation levels, which would indicate subsurface residues. Radiation profiles in the boreholes were determined by measurements of gamma radiation at 15-30 cm intervals between the surface and the hole bottom. A collimated gamma scintillation detector and portable scaler were used for these measurements.

Ground water samples of approximately 3.5 liters each were collected from three boreholes using a hand bailer. Soil samples of approximately 1 kg each were collected from various depths in the holes by

scraping the sides of each borehole with a specially constructed sampling tool. The sampling locations were at depths where gamma logging indicated possible contaminated residues and at additional random depths to adequately characterize the subsurface distribution and levels of radionuclides.

9. Twenty soil samples and seven water samples were collected from the Lewiston area (but not on the NFSS or associated off-site properties) to provide baseline concentrations of radionuclides for comparison purposes. Direct background radiation levels were measured at locations where baseline soil samples were collected. The locations of the baseline samples and background measurements are shown on Figure 6.

Sample Analyses and Interpretation of Results

Soil samples were analyzed by gamma spectrometry. Radium-226 was the major radionuclide of concern, although spectra were reviewed for Cs-137, U-235, U-238, and other gamma emitters. Sr-90 analyses were also performed on soil samples from an area of elevated Ra-226 concentrations and elevated direct radiation levels. Water samples were analyzed for gross alpha and beta concentrations. Additional information concerning analytical equipment and procedures is contained in Appendix A.

Results of this survey were compared to applicable guidelines for formerly utilized radioactive materials handling sites as presented in Appendix B.

RESULTS

Background Levels and Baseline Concentrations

Background exposure rates and baseline radionuclide concentrations in soil, determined for 20 locations (Figure 6) in the vicinity of the NFSS, are presented in Table 1-A. Exposure rates ranged from 6.8 to 8.8 μR/h (typical levels for this area of New York). Concentrations of radionuclides in soil were: Ra-226, <0.09 to 1.22 pCi/g (picocuries per gram); U-235, <0.14 to

0.46 pCi/g; U-238, <2.20 to 6.26 pCi/g; Th-232, 0.32 to 1.18 pCi/g; and Cs-137, <0.02 to 1.05 pCi/g. These concentrations are typical of the radionuclide levels normally encountered in surface soils.

Radioactivity levels in baseline water samples are presented in Table 1-B. The gross alpha and gross beta concentrations ranged from 0.55 to 1.87 pCi/l (picocuries per liter) and <0.63 to 14.3 pCi/l, respectively. These are typical of concentrations normally occurring in surface water.

Direct Radiation Levels

Direct radiation levels, measured at approximately 40 m grid intervals, are presented in Table 2. The gamma exposure rates at 1 m above the surface ranged from 6 to 9 μR/h (average 8 μR/h); contact gamma exposure rates and beta-gamma dose rates at these locations ranged from 6 to 9 μR/h (average 8 μR/h) and 6 to 30 μrad/h (average 17 μrad/h), respectively.

Beta-gamma measurements performed with the G-M detector shielded averaged approximately 20% less than those with the unshielded detector. This indicates only a small portion of the surface dose rate is due to nonpenetrating beta or low-energy photon radiations.

The walkover survey identified several areas on property W with elevated surface radiation levels. These areas are indicated on Figure 4, and associated radiation levels are presented in Table 3.

Gamma exposure rates at contact and at 1 m above the surface at these locations ranged from 17 to 76 μR/h and from 10 to 27 μR/h, respectively. Contact beta-gamma dose rates ranged from 110 to 250 μrad/h. The maximum contact radiation levels were at grid location 83N, 260W. This area and most of the other areas identified by the surface scan were associated with small mounds of earth along the West Drainage Ditch. These mounds are likely sediment dredged from the ditch during previous cleanout of this drainage pathway.

Direct radiation levels were not reduced by sampling; at most locations levels actually increased following removal of soil samples. This suggests that the contamination in these areas extends greater than 15 cm below the surface and/or is diffused rather than in discrete particles.

Radionuclide Concentrations in Surface Soil

Table 4 lists the concentrations of radionuclides measured in surface soil samples collected from approximately 40 m grid intervals. Ra-226 concentrations ranged from <0.15 to 1.23 pCi/g - not significantly different from baseline levels. Other radionuclides in these samples were also in the ranges of baseline concentrations.

Radionuclide concentrations in surface soil samples, collected from locations of elevated radiation levels are presented in Table 5. The samples contained Ra-226 concentrations ranging from 25.3 to 102 pCi/g. The highest concentration was measured in sample B3 from grid location 81N, 252W. This sample was from one of the mounds of earth along the West Drainage Ditch. Levels of U-235 and U-238 were also elevated in these samples; however, Ra-226 is the most significant radionuclide. Sample B6 from location 99N, 240W was also analyzed for Sr-90 and found to contain only a small level (0.35 ± 0.19 pCi/g) of this radionuclide.

Borehole Gamma-logging Measurements

Gamma scintillation measurements performed in boreholes indicated no subsurface contamination in most borehole locations and that contamination in the mounds of dredged ditch sediments is limited to the upper 60-90 cm, i.e. the approximate depth of the mounds. As evidenced by soil sample analysis, the gamma count rates determined by the borehole measurements were reliable indicators of elevated subsurface radionuclide levels. However, the gamma-logging data were not used to quantify radionuclide concentrations in the subsurface soil, because of the varying ratios of Ra-226, U-235, U-238, and Cs-137 occurring in soils from this site.

Radionuclide Concentrations in Subsurface Soil

Table 6 presents the radionuclide concentrations measured in soil samples from boreholes. The five boreholes (H1-H5) at locations selected to provide a representative coverage of the property, had subsurface radionuclide concentrations either in the range of baseline samples or less than the minimum detectable activity (MDA).

Boreholes H6-H8 were at locations where the walkover scan had identified possible contamination. Subsurface samples from these boreholes contained Ra-226 levels ranging from 1.01 to 81.5 pCi/g; however, only one of these samples (at the 0.15 cm depth in borehole H8) exceeded 4.20 pCi/g. Samples from the surface and at 15 cm deep in borehole H8 contained Sr-90 concentrations of 0.35 ± 0.19 and 0.23 ± 0.18 pCi/g, respectively. Concentrations of other radionuclides were much lower, most being in the range of baseline samples.

Radionuclide Concentrations in Subsurface Water

Water samples obtained from three boreholes contained gross alpha and gross beta concentrations ranging from <0.66 to 7.09 pCi/1 and from 1.00 to 6.88 pCi/1, respectively. Since concentrations were below the EPA drinking water criteria of 15 pCi/1 gross alpha and 50 pCi/1 gross beta, no additional isotopic analyses were performed on these samples.

COMPARISON OF SURVEY RESULTS WITH GUIDELINES

The guidelines applicable to cleanup of the off-site properties at NFSS are presented in Appendix B. The maximum gamma exposure rate measured at 1 m above the surface was 9 μR/h - not signficantly different from background levels and well below the 60 μR/h Nuclear Regulatory Commission criteria for open land areas.

The results of the walkover surface scan and analysis of soil samples from selected locations of elevated direct radiation levels indicate that isolated areas of Ra-226 surface soil contamination, averaged over 100 m^2,

exceed 5 pCi/g above baseline levels. These areas, shown on Figure 7, are associated with small mounds of earth, apparently removed from the West Drainage Ditch and located along the east bank of the ditch. Subsurface measurements and samples indicate that concentrations of Ra-226 exceeding 15 pCi/g are within 0.5 m of the surface and are limited to a small area. If averaged over an area of 100 m^2, the concentration would not exceed the 15 pCi/g criteria. Concentrations of other radionuclides in surface and subsurface soil are within the guidelines for NFSS off-site properties.

Subsurface water samples from three boreholes were within the EPA Interim Drinking Water Standards of 15 pCi/l gross alpha and 50 pCi/l gross beta.

SUMMARY

A comprehensive survey of off-site property W at the Niagara Falls Storage Site was conducted during July 1983. The survey included surface radiation scans, measurements of direct radiation levels, and analyses of radionuclide concentrations in surface and subsurface soil samples and in subsurface water samples. The West Drainage Ditch is already scheduled for cleanup and resurvey by Bechtel National, Inc. and was therefore not included in the ORAU survey.

The results of the survey indicate small mounds of earth, apparently dredged from the West Drainage Ditch, containing Ra-226 concentrations exceeding the cleanup criteria of 5 pCi/g for surface soils. These areas, shown on Figure 7, cover approximately 80 m^2 and average approximately 15 cm deep. About 12.5 m^3 of soil would have to be removed to bring this property into compliance with criteria for unrestricted use.

Although there are small areas of contaminated residues on portions of this property, the contaminants do not pose potential health risks. There is no evidence that migration of the radioactive materials is adversely affecting adjacent properties or the ground water.

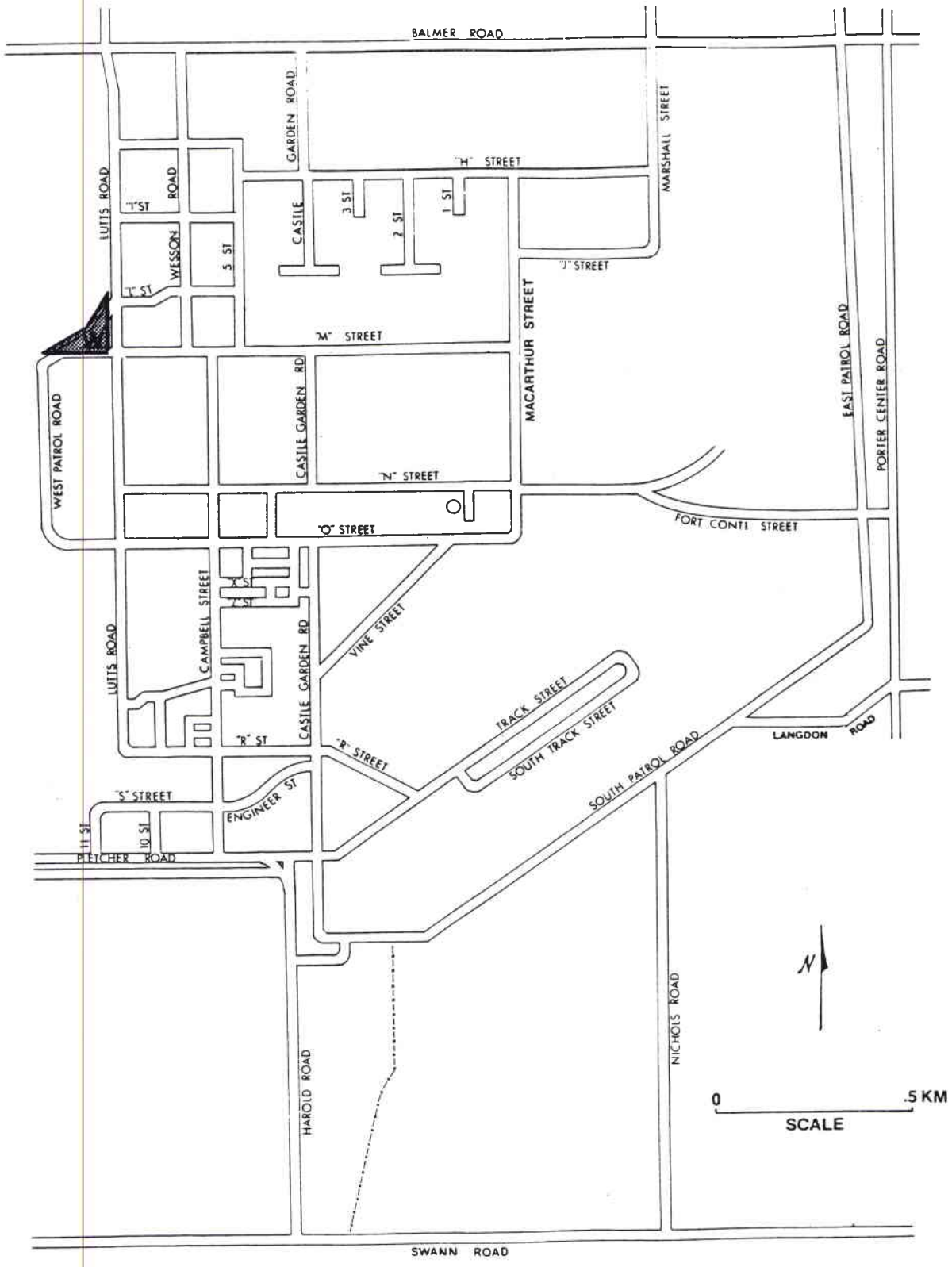

FIGURE 1. Map of Niagara Falls Storage Site and Off-Site Properties, Lewiston, New York, Indicating the Location of Off-Site Property W.

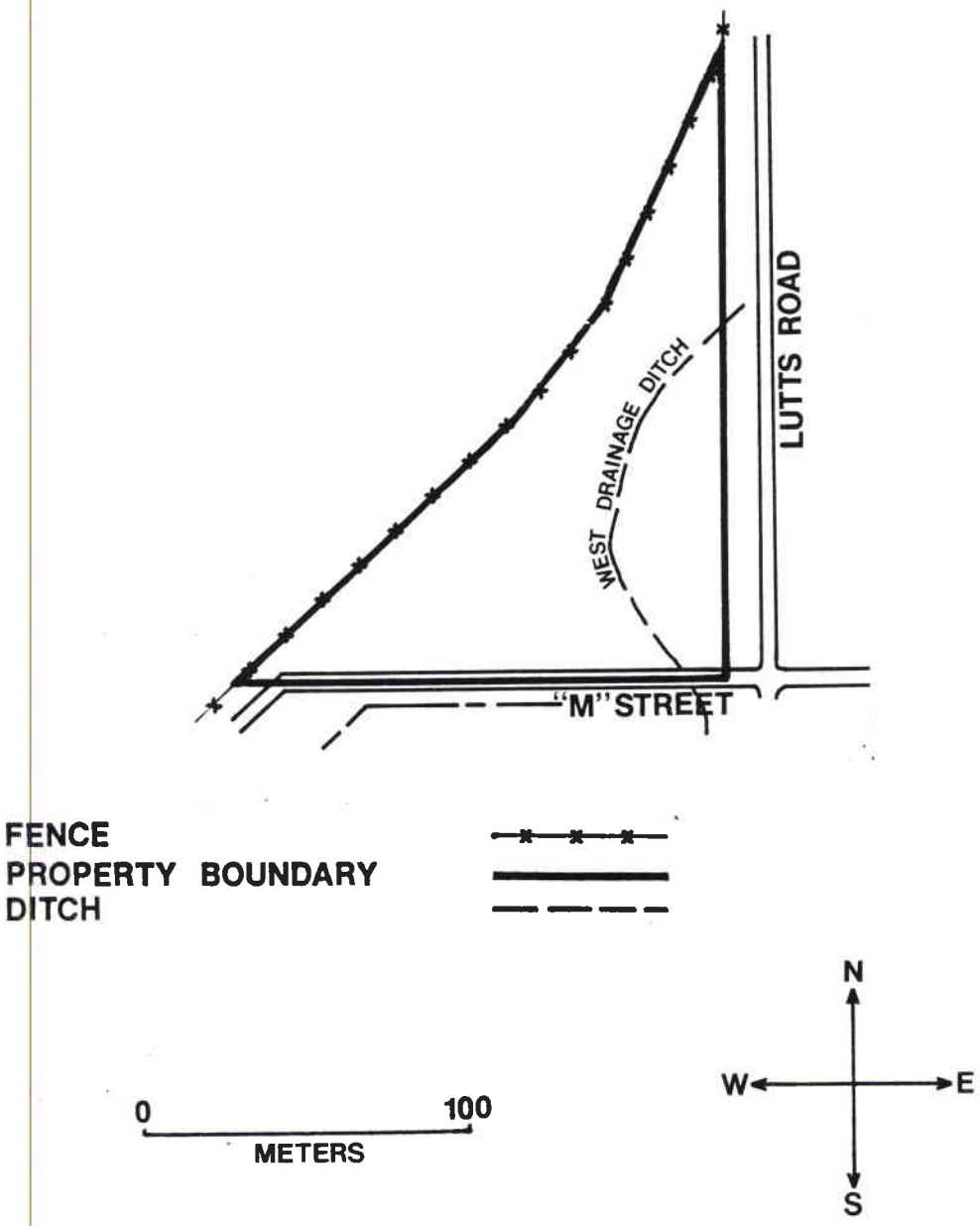

FIGURE 2. Plan View of Off-Site Property W Indicating Prominent Surface Features.

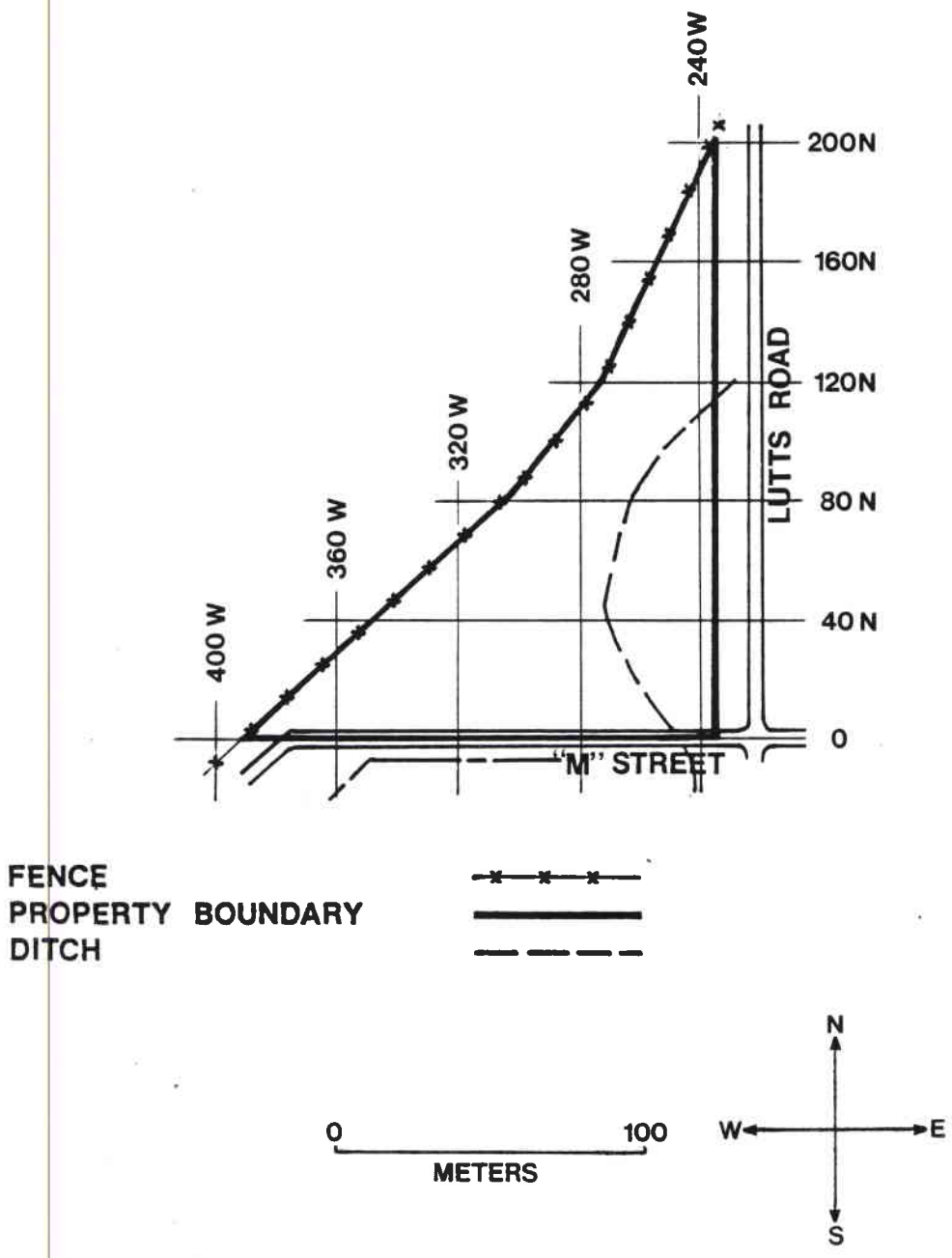

FIGURE 3. Map of Off-Site Property W Indicating the Grid System Established for Survey Reference.

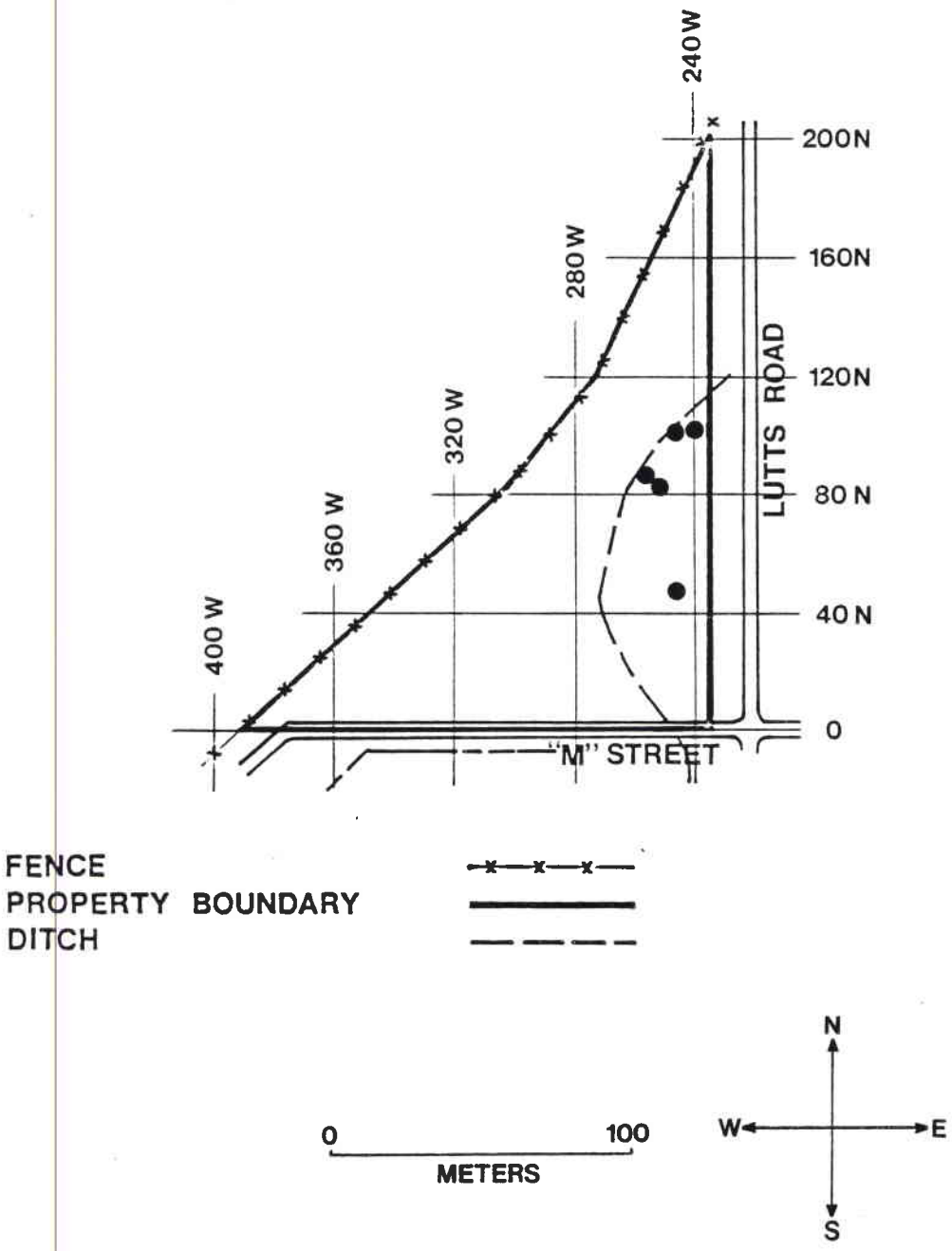

FIGURE 4. Locations of Elevated Direct Radiation Levels Identified by the Walkover Scan.

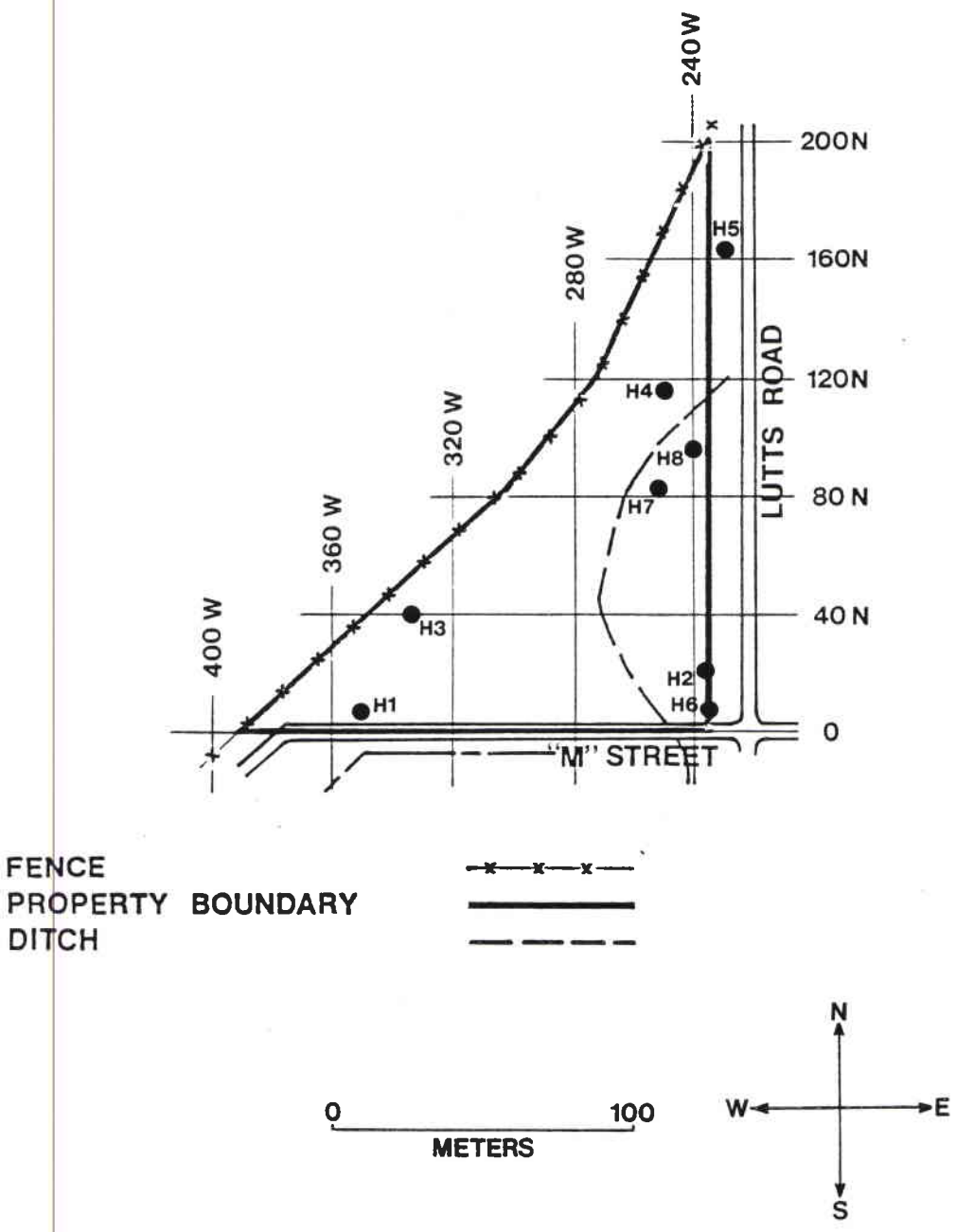

FIGURE 5. Locations of Boreholes for Subsurface Investigations.

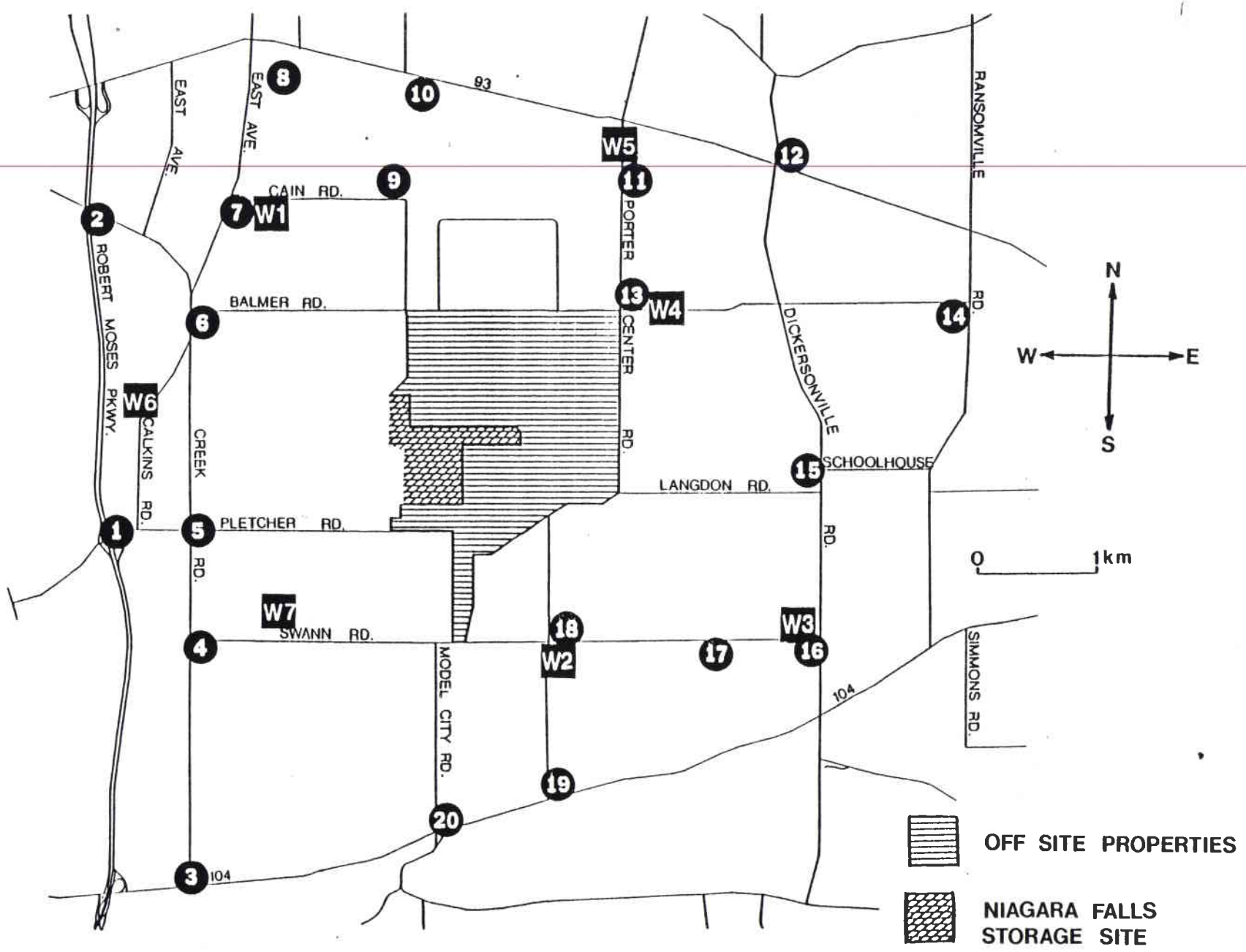

FIGURE 6. Map of Northern Niagara County, New York, Showing Locations of Background Measurements and Baseline Samples (#1-20: Soil Samples and Direct Measurements; W1-W7: Water Samples).

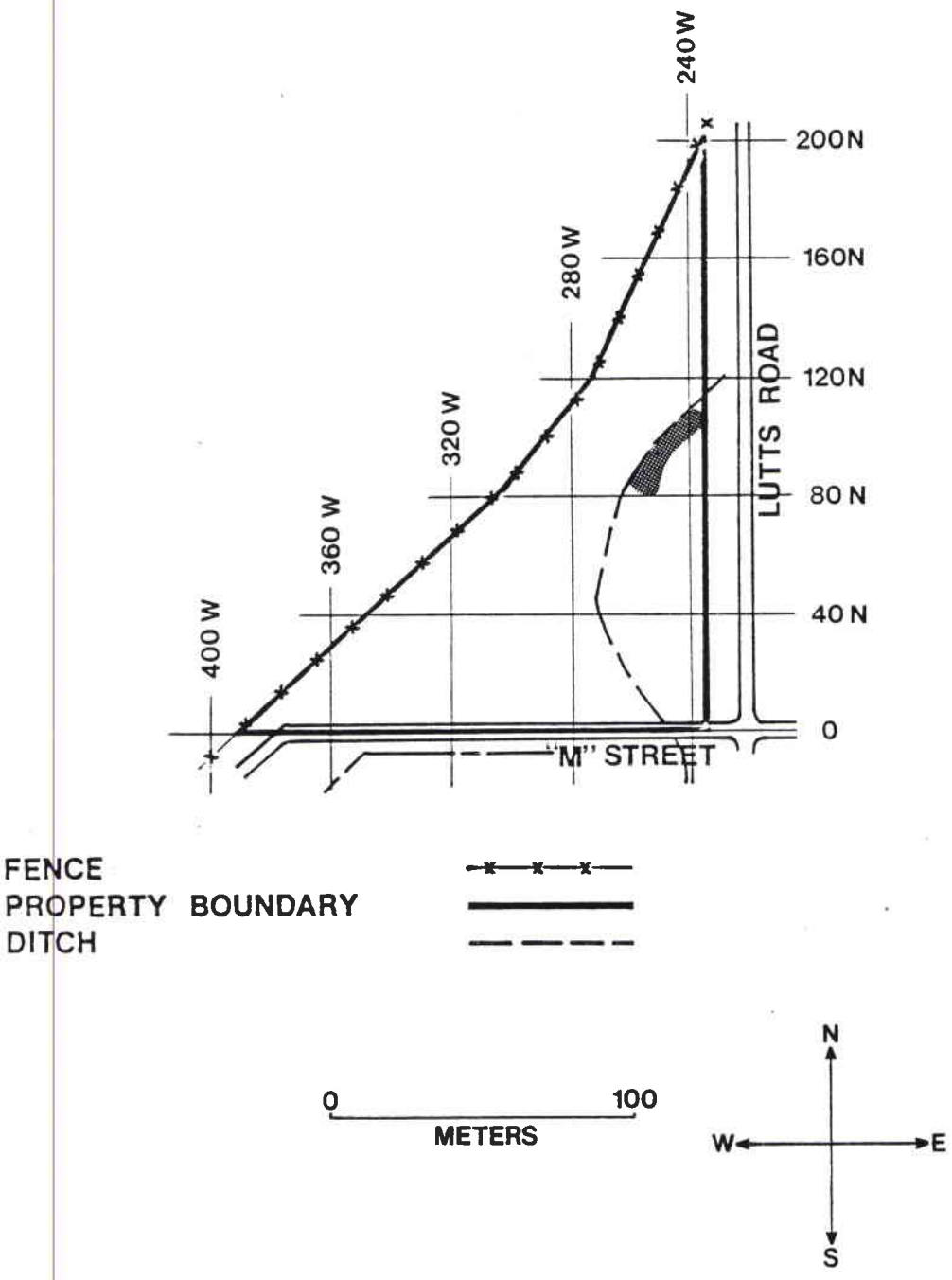

FIGURE 7. Map of NFSS Off-Site Property W Indicating Locations (Shaded) Where Ra-226 Concentrations in Soil Exceed Criteria Levels.

TABLE 1-A

BACKGROUND EXPOSURE RATES
AND
RADIONUCLIDE CONCENTRATIONS IN BASELINE SOIL SAMPLES

Location [a]	Exposure Rate [b] (μR/h)	Radionuclide Concentrations (pCi/g)				
		Ra-226	U-235	U-238	Th-232	Cs-137
1	6.8	0.74 ± 0.16 [c]	<0.19	<2.89	0.70 ± 0.46	0.29 ± 0.08
2	6.8	0.75 ± 0.19	<0.19	<3.35	0.86 ± 0.24	0.24 ± 0.08
3	8.3	0.71 ± 0.18	0.46 ± 0.41	<3.72	0.88 ± 0.33	0.34 ± 0.09
4	7.9	0.67 ± 0.18	<0.22	<4.10	1.18 ± 0.35	0.12 ± 0.07
5	7.3	0.70 ± 0.16	<0.17	<3.34	0.68 ± 0.24	0.14 ± 0.07
6	7.7	0.50 ± 0.15	<0.16	<2.33	0.52 ± 0.38	0.17 ± 0.09
7	7.7	0.63 ± 0.13	<0.17	<2.73	0.83 ± 0.24	0.35 ± 0.08
8	7.6	0.59 ± 0.12	<0.14	<2.20	0.54 ± 0.23	<0.02
9	7.1	0.63 ± 0.20	<0.23	<4.16	0.83 ± 0.38	0.69 ± 0.11
10	7.1	0.70 ± 0.16	<0.19	<2.98	0.59 ± 0.25	0.69 ± 0.10
11	6.7	<0.09	<0.19	<2.83	0.49 ± 0.31	0.48 ± 0.14
12	7.1	0.48 ± 0.13	<0.16	<2.84	0.65 ± 0.26	0.68 ± 0.10
13	6.7	0.57 ± 0.14	<0.17	<2.36	0.49 ± 0.26	0.41 ± 0.08
14	6.8	0.68 ± 0.17	<0.19	<3.24	0.67 ± 0.25	0.70 ± 0.10
15	8.2	0.65 ± 0.14	<0.17	<3.20	0.72 ± 0.35	0.23 ± 0.08
16	7.4	0.91 ± 0.17	<0.71	<3.58	0.83 ± 0.28	0.61 ± 0.09
17	7.0	0.48 ± 0.14	<0.16	<2.73	0.32 ± 0.22	0.38 ± 0.08
18	7.7	0.73 ± 0.16	<0.18	6.26 ± 9.23	1.01 ± 0.44	0.32 ± 0.12
19	8.8	1.22 ± 0.22	<0.23	<3.79	1.08 ± 0.49	1.05 ± 0.13
20	8.6	0.83 ± 0.17	<0.21	<3.59	0.84 ± 0.29	0.08 ± 0.07
Range	6.8 to 8.8	<0.09 to 1.22	<0.14 to 0.46	<2.20 to 6.26	0.32 to 1.18	<0.02 to 1.05

[a] Refer to Figure 6.
[b] Measured at 1 m above the surface.
[c] Errors are 2σ based on counting statistics.

TABLE 1-B

RADIONUCLIDE CONCENTRATIONS IN BASELINE WATER SAMPLES

Location[a]	Radionuclide Concentrations (pCi/l)	
	Gross Alpha	Gross Beta
W1	0.95 ± 0.93 [b]	4.79 ± 1.15
W2	0.95 ± 0.94	9.17 ± 1.31
W3	0.55 ± 0.78	2.73 ± 1.05
W4	0.63 ± 0.89	5.37 ± 1.17
W5	0.73 ± 0.68	<0.64
W6	1.87 ± 1.84	14.3 ± 2.4
W7	1.16 ± 0.66	<0.63
Range	0.55 to 1.87	<0.63 to 14.3

[a] Refer to Figure 6.
[b] Errors are 2σ based on counting statistics.

TABLE 2

DIRECT RADIATION LEVELS MEASURED
AT APPROXIMATELY 40 M GRID INTERVALS

Grid Location	Gamma Exposure Rates at 1 m Above the Surface (μR/h)	Gamma Exposure Rates at the Surface (μR/h)	Beta-Gamma Dose Rates at 1 cm Above the Surface (μrad/h)
0 ,240W	6	6	7
0 ,280W	6	6	6
0 ,320W	6	6	6
0 ,360W	6	6	6
0 ,380W	7	7	30
40N,240W	8	8	16
40N,280W	9	8	11
40N,320W	8	8	14
40N,350W	8	8	26
80N,240W	9	9	19
80N,280W	8	8	17
80N,300W	8	8	30
120N,240W	9	8	26
120N,278W	8	8	8
160N,240W	7	8	22
200N,235W	8	8	21

TABLE 3

DIRECT RADIATION LEVELS AT LOCATIONS
IDENTIFIED BY THE WALKOVER SURFACE SCAN

Grid Point	Exposure Rate (μR/h)		Surface Dose Rate (μrad/h)	Sample[a] Identification	Contact Exposure Rate after Sample Removal (μR/h)
	Contact	1 m above surface			
46N,246W	22	10	110	B1	17
80-83N,251-255W	29-68	---[b]	---	---	---
80N,253W	43	27	160	B2	40
81N,252W	68	27	120	B3	90
81N,254W	53	23	220	B4	57
83N,260W	76	20	250	B5	90
95N,250W	54	---	---	---	---
97-102N,238-242W	17-45	---	---	---	---
99N,240W	45	21	130	B6	68
98-103N,250-253W	29-55	---	---	---	---
100N,250W	36	---	---	---	---
102N,252W	55	---	---	---	---
102N,253W	42	---	---	---	---

[a] Soil concentrations presented in Table 4.
[b] Dash indicates measurement or sampling was not performed.

TABLE 4

RADIONUCLIDE CONCENTRATIONS IN SURFACE SOIL SAMPLES
FROM APPROXIMATELY 40 M GRID INTERVALS

Grid Location	Radionuclide Concentrations (pCi/g)			
	Ra-226	U-235	U-238	Cs-137
0 240W	1.23 ± 0.28[a]	<0.22	<0.78	0.83 ± 0.14
0 280W	1.03 ± 0.23	<0.29	<0.86	1.33 ± 0.16
0 320W	0.87 ± 0.19	<0.29	<4.92	0.65 ± 0.14
0 360W	0.54 ± 0.18	0.33 ± 0.40	<0.63	0.81 ± 0.11
0 380W	1.00 ± 0.20	0.59 ± 0.47	<0.74	0.33 ± 0.10
40N 240W	0.58 ± 0.22	<0.17	0.96 ± 0.92	0.36 ± 0.15
40N 280W	0.68 ± 0.20	<0.29	4.67 ± 1.68	0.42 ± 0.09
40N 320W	1.00 ± 0.27	<0.22	0.94 ± 1.66	0.31 ± 0.15
40N 350W	0.82 ± 0.22	<0.28	3.06 ± 1.31	0.42 ± 0.09
80N 240W	0.71 ± 0.25	<0.22	<0.65	0.54 ± 0.11
80N 280W	<0.15	<0.21	1.58 ± 1.97	<0.08
80N 300W	0.68 ± 0.21	<0.27	<0.83	0.38 ± 0.09
120N 240W	0.80 ± 0.24	<0.27	<0.85	0.22 ± 0.08
120N 278W	0.51 ± 0.23	<0.27	<0.85	0.43 ± 0.09
160N 240W	0.58 ± 0.17	<0.19	1.63 ± 1.67	0.39 ± 0.13
200N 235W	0.58 ± 0.18	<0.20	2.14 ± 1.12	<0.03

[a] Errors are 2σ based on counting statistics.

TABLE 5

RADIONUCLIDE CONCENTRATIONS IN SURFACE SAMPLES
FROM SELECTED LOCATIONS IDENTIFIED BY THE WALKOVER SCAN

Sample Identification	Grid Location	Radionuclide Concentrations (pCi/g)[a]			
		Ra-226	U-235	U-238	Cs-137
B1	46N,246W	55.0 ± 1.8[b]	1.83 ± 2.30	<3.66	0.51 ± 0.17
B2	80N,253W	81.8 ± 1.8	<1.42	9.31 ± 5.68	<0.16
B3	81N,252W	102 ± 2	<1.30	<3.58	0.90 ± 0.23
B4	81N,254W	66.1 ± 1.8	4.14 ± 2.21	4.73 ± 5.30	0.80 ± 0.17
B5	83N,260W	25.3 ± 4.9	7.05 ± 3.94	10.8 ± 11.4	1.64 ± 0.40
B6[c]	99N,240W	91.4 ± 2.1	1.36 ± 2.60	<4.67	1.31 ± 0.26

[a] Refer to Table 3 for direct radiation levels.
[b] Errors are 2σ based on counting statistics.
[c] Also contains 0.35 ± 0.19 pCi/g of Sr-90.

TABLE 6

RADIONUCLIDE CONCENTRATIONS IN BOREHOLE SOIL SAMPLES

Borehole No.[a]	Grid Location	Depth (m)	Radionuclide Concentrations (pCi/g)			
			Ra-226	U-235	U-238	Cs-137
H1	4N,351W	Surface	0.81 ± 0.33[b]	<0.27	<0.88	0.28 ± 0.10
		0.5	0.95 ± 0.23	<0.19	<0.80	<0.04
		1.0	1.29 ± 0.33	<0.35	2.70 ± 2.27	<0.05
		2.0	0.81 ± 0.20	<0.31	1.35 ± 0.96	<0.04
H2	20N,236W	Surface	0.78 ± 0.28	<0.31	0.83 ± 1.85	0.37 ± 0.11
		0.5	1.00 ± 0.26	<0.24	<0.85	<0.04
		1.0	0.69 ± 0.16	<0.28	<0.85	<0.03
		2.0	0.55 ± 0.16	<0.18	1.58 ± 1.83	<0.03
H3	40N,335W	Surface	0.68 ± 0.26	<0.19	1.84 ± 1.38	0.15 ± 0.06
		0.5	1.15 ± 0.26	<0.33	<1.06	<0.04
		1.0	0.83 ± 0.23	<0.20	<0.70	<0.02
		2.0	0.88 ± 0.24	<0.28	<0.95	<0.04
H4	118N,255W	Surface	1.01 ± 0.29	<0.27	<0.87	<0.04
		0.5	0.65 ± 0.23	<0.22	1.79 ± 1.50	<0.04
		1.0	0.84 ± 0.35	<0.27	<0.80	<0.04
		2.0	0.85 ± 0.18	<0.19	0.94 ± 1.42	<0.03
H5	160N,229W	Surface	0.83 ± 0.20	<0.25	1.36 ± 1.43	0.12 ± 0.04
		0.5	0.79 ± 0.21	<0.21	<0.69	<0.03
		1.0	1.01 ± 0.24	<0.26	2.19 ± 1.93	<0.04
		2.0	0.98 ± 0.29	<0.25	1.72 ± 1.81	<0.04
H6	4N,235W	Surface	4.00 ± 0.49	<0.29	1.75 ± 1.89	0.25 ± 0.08
		0.3	1.15 ± 0.25	<0.28	<0.92	<0.04
		0.6	1.29 ± 0.25	<0.26	1.61 ± 1.77	0.08 ± 0.13

TABLE 6, Cont.

RADIONUCLIDE CONCENTRATIONS IN BOREHOLE SOIL SAMPLES

Borehole No.	Grid Location	Depth (m)	Radionuclide Concentrations (pCi/g)			
			Ra-226	U-235	U-238	Cs-137
H7	81N,252W	Surface	102 ± 2	<1.30	<3.58	0.90 ± 0.23
		0.15	3.93 ± 0.44	<0.39	1.60 ± 2.02	0.20 ± 0.09
		0.5	2.19 ± 0.30	<0.33	0.90 ± 1.45	<0.05
		2.0	1.01 ± 0.24	<0.29	<0.94	<0.04
H8[c]	99N,240W	Surface	91.4 ± 2.1	1.36 ± 2.60	<4.67	1.31 ± 0.26
		0.15	81.5 ± 2.0	3.23 ± 2.51	<4.39	0.42 ± 0.18
		0.5	3.59 ± 0.44	<0.30	<0.86	<0.04
		1.0	4.20 ± 0.49	<0.40	3.15 ± 1.44	<0.04
		2.0	2.38 ± 0.29	0.33 ± 0.54	<0.73	<0.04

[a] Refer to Figure 5.
[b] Errors are 2σ based on counting statistics.
[c] Also contains 0.35 ± 0.19 pCi/g of Sr-90 at surface and 0.23 ± 0.18 pCi/g of Sr-90 at 0.15 m depth.

TABLE 7

RADIONUCLIDE CONCENTRATIONS IN BOREHOLE WATER SAMPLES

Sample Identification	Sample Type	Grid Location	Radionuclide Concentrations (pCi/l)	
			Gross Alpha	Gross Beta
W1	Subsurface (Borehole H2)[a]	20N,236W	<0.66	1.00 ± 1.08[b]
W2	Subsurface (Borehole H3)	40N,335W	7.09 ± 3.88	6.88 ± 3.61
W3	Subsurface (Borehole H5)	160N,229W	4.23 ± 1.49	6.62 ± 1.42

[a] Refer to Figure 5.
[b] Errors are 2σ based on counting statistics.

REFERENCES

1. E.A. Vierzba and A. Wallo, Background Report and Resurvey Recommendations for the Atomic Energy Commission Portion of the Lake Ontario Ordnance Works, Aerospace Corp., November 1982.

2. Oak Ridge Operations, U.S. Atomic Energy Commission, Radiation Survey and Decontamination Report of the Lake Ontario Ordnance Works Site, Oak Ridge, TN, January 1973.

3. T.E. Myrick, et al., Preliminary Results of the Ground-Level Gamma-Ray Scanning Survey of the Former Lake Ontario Ordnance Works Site - Draft Report, ORNL, Oak Ridge, TN, 1981.

4. B.S. Ausmus, et al., Comprehensive Radiological Survey of the DOE - Niagara Falls Storage Site, BMI-2061 Battelle Columbus Laboratories, August 1980.

APPENDIX A

INSTRUMENTATION AND ANALYTICAL PROCEDURES

APPENDIX A

Instrumentation and Analytical Procedures

Gamma Scintillation Measurement

Walkover surface scans and measurements of gamma exposure rates were performed using Eberline Model PRM-6 portable ratemeters with Victoreen Model 489-55 gamma scintillation probes containing 3.2 cm x 3.8 cm NaI(Tl) scintillation crystals. Count rates were converted to exposure levels (μR/h) using factors determined by comparing the response of the scintillation detector with that of a Reuter Stokes Model RSS-111 pressurized ionization chamber at several locations on the NFSS and off-site properties.

Beta-Gamma Dose Rate Measurements

Measurements were performed using Eberline "Rascal," Model PRS-1, portable scaler/ratemeters with Model HP-260 thin-window, pancake G-M, beta probes. Dose rates (μrad/h) were determined by comparison of the response of a Victoreen Model 440 ionization chamber survey meter to that of the G-M probes.

Borehole Logging

Borehole gamma radiation measurements were performed using a Victoreen Model 489-55 gamma scintillation probe, connectd to a Ludlum Model 2200 portable scaler. The scintillation probe was shielded by a 1.25 cm thick lead shield with four 2.5 cm x 7 mm holes evenly spaced around the region of the scintillation crystal. The probe was lowered into each hole using a tripod holder with a small winch. The length of the hole was scanned and measurements were performed at 15-30 cm intervals in all holes. The logging data were used to identify regions of possible residues and guide the selection of subsurface soil sampling locations. Due to the varying ratios of Ra-226, U-235, U-238, and Cs-137 there was no attempt to estimate soil radionuclide concentrations directly from the logging results.

Soil Sample Analysis

Soil samples were dried, mixed, and a portion placed in a 0.5 liter Marinelli beaker. The quantity placed in each beaker was chosen to reproduce the calibrated counting geometry and typically ranged from 600 to 800 g of soil. Net soil weights were determined and samples counted using solid state Ge(Li) and intrinsic germanium detectors coupled to a Nuclear Data Model ND-680 pulse height analyzer system. Background and Compton stripping peak search, peak identification, and concentration calculations were performed using the computer capabilities inherent in the analyzer system. Energy peaks used for determination of radionuclides of concern were:

Ra-226 - 0.609 MeV from Bi-214 (corrected for equilibrium conditions)
U-235 - 0.143 MeV
U-238 - 0.094 MeV from Th-234 (secular equilibrium assumed)
Cs-137 - 0.662 MeV

Strontium-90 analysis was performed following standard procedures specified in "Radiochemical Analytical Procedures for Analysis of Environmental Samples," EMSL-LV-0539-17, March 1979.

Water Sample Analysis

Water samples were rough-filtered through Whatman No. 2 filter paper. Remaining suspended solids were removed by subsequent filtration through 0.45 μm membrane filters. The filtrate was acidified by addition of 10 ml of concentrated nitric acid. A known volume of each sample was evaporated to dryness and counted for gross alpha and gross beta using a Tennelec Model LB5100 low-background proportional counter.

Calibration and Quality Assurance

With the exception of the exposure and dose rate conversion factors for portable survey gamma and beta-gamma meters, all survey and laboratory instruments were calibrated with NBS-traceable standards. The calibration procedures for these portable instruments are described above.

Quality control procedures on all instruments included daily background and check-source measurements to confirm lack of malfunctions and nonstatistical deviations in equipment. The ORAU laboratory participates in the EPA Quality Assurance Program.

APPENDIX B

SUMMARY OF RADIATION GUIDELINES APPLICABLE TO OFF-SITE PROPERTIES AT THE NIAGARA FALLS STORAGE SITE

U. S. DEPARTMENT OF ENERGY

RESIDUAL CONTAMINATION AND WASTE CONTROL CRITERIA FOR FORMERLY UTILIZED SITES REMEDIAL ACTION PROGRAM (FUSRAP) AND REMOTE SURPLUS FACILITIES MANAGEMENT PROGRAM (SFMP) SITES

Presented here are the residual contamination cleanup and waste control criteria of general applicability to the FUSRAP project and remote SFMP sites[1/].

With the exception of limits for radium-226, the soil residual contamination criteria were developed on the basis of limiting maximum individual radiation exposure to DOE limits specified in DOE Order 5480.1A exclusive of exposure from natural background radiation or medical procedures. The aggregate of the contribution from all major pathways, based on scenarios for permanent intrusion, e.g., establishing residences on the site, has been assumed. In most circumstances, the probability is low that such an intrusion will occur. Also, conservative assumptions were used in deriving these criteria to ensure that a particular dose limit would not be exceeded. Use of these criteria is additionally conservative because the pathways considered in the derivation of the criteria assume all water intake and most food intake is from the site. Also, the sites often have limited agricultural capability and the contamination is generally not homogeneous. The combined effect of these factors is such that the probable radiation exposure to the average population on, or in the vicinity of, FUSRAP sites decontaminated to these criteria limits will not be appreciably different from that normally received from natural background radiation.

The residual contamination criteria for surface contamination of structures were developed from a proposed ANSI standard[2/] modified as appropriate to be consistent with DOE Order 5480.1A and the specific needs of FUSRAP for cost-effective, workable guidelines which provide an adequate safety margin. The waste control criteria are consistent with applicable DOE Orders and EPA's regulations for inactive uranium milling sites, 40 CFR 192.

1/ A remote SFMP site is one that is excess to DOE programmatic needs and is located outside a major operating DOE R&D or production area. Remote sites are more likely to be released to the public or excessed to other government agencies after decontamination than are sites located with major R&D or production areas.

2/ ANSI N13.12 (proposed) -- an adaptation to be applied, as appropriate.

A. RESIDUAL CONTAMINATION CRITERIA FOR FORMERLY UTILIZED SITES AND REMOTE SURPLUS FACILITIES MANAGEMENT PROGRAM SITES

The following criteria represent the maximum residual contamination limits for unrestricted use of land and structures contaminated with radionuclides related to the nuclear fuel cycle at FUSRAP and remote SFMP sites. It is the policy of DOE to decontaminate sites to contamination levels at or below the limits and in a manner consistent with DOE's as-low-as-is-reasonably-achievable (ALARA) policy. Residual contamination limits for other nuclides will be developed when required using the same methodology[1/] as was used for those represented here.

1. Soil (Land) Criteria (Maximum Limits for Unrestricted Use)

Radionuclide	Soil Criteria[2/,3/,4/] (pCi/g above background)
U-Natural[5/]	75
U-238[6/]	150
U-234[6/]	150
Th-230[7/]	15
Ra-226	5 pCi/g, averaged over the first 15 cm of soil below the surface; 15 pCi/g when averaged over 15 cm thick soil layers more than 15 cm below the surface and less than 1.5m below the surface.
U-235[6/]	140
Pa-231	40
Ac-227	190
Th-232	15
Am-241	20
Pu-241[8/]	800
Pu-238, 239, 240	100
Cs-137	80
Sr-90	100
H-3 (pCi/ml soil moisture)	5,200

1/ Described in ORO-831 and ORO-832.

2/ In the event of occurrence of mixtures of radionuclides, the fraction contributed by each radionuclide to its limit shall be determined, and the sum of these fractions shall not exceed 1. There are two special cases for which this rule must be modified:

(a) If Ra-226 is present, then the fraction for Ra-226 should not be included in the sum if the Ra-226 concentration is less than or equal to the Th-230 concentration. If the Ra-226 concentration exceeds the Th-230 concentration, then the sum shall be evaluated by replacing the Ra-226 concentration by the difference between the Ra-226 and Th-230 concentrations.

(b) If Ac-227 is present, then the same rule given in (a) for Ra-226 relative to Th-230 applies for Ac-227 relative to Pa-231.

3/ Except for Ra-226, these criteria represent unrestricted-use residual concentrations above background averaged across any 15 cm thick layer to any depth and over any contiguous 100 m^2 surface area. The same conditions prevail for Ra-226 except for soil layers beneath 1.5 m; beneath 1.5 m, the allowable Ra-226 concentration may be affected by site-specific conditions and must be evaluated accordingly.

4/ Localized concentrations in excess of these limits are allowable provided that the average over 100 m^2 is not exceeded.

5/ A curie of natural uranium means the sum of 3.7×10^{10} disintegrations per second (dis/s) from U-238 plus 3.7×10^{10} dis/s from U-234 plus 1.7×10^{5} dis/s from U-235. One curie of natural uranium is equivalent to 3,000 kilograms or 6,600 pounds of natural uranium.

6/ Assumes no other uranium isotopes are present.

7/ The Th-230 guideline is 15 pCi/g to account for ingrowth of Ra-226 as Th-230 decays. Ra-226 is a limiting radionuclide because its decay product is Rn-222 gas.

8/ The Pu-241 criterion was derived from the Am-241 concentration.

2. Structure Criteria (Maximum Limits for Unrestricted Use)

a. Indoor Radon Decay Products

A structure located on private property and intended for unrestricted use shall be subject to remedial action as necessary to ensure the annual average concentration of radon decay products is less than 0.03 WL within the structure.

b. Indoor Gamma Radiation

The indoor gamma radiation after decontamination shall not exceed 20 microroentgen per hour (20 μR/h) above background.

c. Indoor/Outdoor Structure Surface Contamination

Radionuclides	Allowable Surface Residual Contamination[1] (dpm/100 cm^2) Total	Removable
Group 1:	100	20
Radionuclides for which the uncontrolled area concentration guide in air above background[2] is 2×10^{-13} Ci/m^3 or less or for which the uncontrolled area concentration guide in water above background[2] is 2×10^{-7} Ci/m^3 or less; includes Pa-231, Th-228, Th-230, Ac-227, Ra-226, Ra-228, and Pb-210.		
Group 2:	1,000	200
Radionuclides not in Group 1 for which the uncontrolled area concentration guide in air above background[2] is 1×10^{-12} Ci/m^3 or less or for which the uncontrolled area concentration guide in water above background[2] is 1×10^{-6} Ci/m^3 or less; includes U-232, U-238, Th-232, Ra-223, and Po-210.		
Group 3:	5,000	1,000
Those radionuclides not in Group 1 or Group 2; includes U-234, U-235, and Ra-224 and all other beta-gamma emitters.		

[1] The levels may be averaged over 1 m^2 provided the maximum activity in any area of 100 cm^2 is less than 3 times the limit value; dpm = disintegrations per minute. In the event of occurrence of mixtures of radionuclides, the fraction contributed by each radionuclide to its limit shall be determined, and the sum of these fractions shall not exceed 1.

[2] Given in Attachment 1 to Chapter XI, Table II, DOE Order 5480.1A.

B. CONTROL OF RADIOACTIVE WASTES AND RESIDUES FROM FUSRAP AND REMOTE SFMP SITES

Specified here are the control requirements (criteria) for radioactive wastes and residues related to the nuclear fuel cycle at FUSRAP and remote SFMP sites.

1. Interim Storage

All operational and control requirements specified in the following DOE Orders shall apply:

a. 5480.1A, Environmental Protection, Safety, and Health Protection Program for DOE Operations.

b. 5480.2, Hazardous and Radioactive Mixed Waste Management.

c. 5483.1, Occupational Safety and Health Program for Government-Owned Contractor-Operated Facilities.

d. 5484.1, Environmental Protection, Safety, and Health Protection Information Reporting Requirements.

e. 5484.2, Unusual Occurrence Reporting System.

f. Control and stabilization features will be designed to ensure, to the extent reasonably achievable, an effective life of 50 years, and in any case, at least 25 years.

g. Rn-222 concentrations in the atmosphere above facility surfaces or openings shall not (1) exceed 100 pCi/l at any given point, or an average concentration of 30 pCi/l for the facility site, or (2) exceed an average Rn-222 concentration at or above any location outside the facility site of 3.0 pCi/l (above background).

h. For water protection, use existing state and federal standards; apply site-specific measures where needed.

2. Long-Term Management

a. All operational requirements specified for Interim Storage Facilities (B.1) will apply.

b. Control and stabilization features will be designed to ensure to the extent reasonably achievable, an effective life of 1,000 years and, in any case, at least 200 years. Other disposal site design features shall conform with 40 CFR Part 192 performance guidelines/requirements.

c. Rn-222 emanation to the atmosphere from facility surfaces or opening shall not (1) exceed an average release rate of 20 $pCi/m^2/s$, or (2) increase the annual average Rn-222 concentration at or above any location outside the facility site by more than 0.5 pCi/l.

d. For water protection, use existing state and federal standards; apply site-specific measures where needed.

e. Prior to placement of any potentially biodegradable contaminated wastes in a Long-Term Management Facility, such wastes will be properly conditioned to (1) ensure that the generation and escape of biogenic gases will not cause the criteria in paragraph 2.c. to be exceeded, and (2) ensure that biodegradation within the facility will not result in premature structural failure not in accordance with the criteria in paragraph 2.b.. If biodegradable wastes are conditioned by incineration, incineration operations will be carried out in compliance with all applicable federal, state, and local air emission standards and requirements, including any standards for radionuclides established pursuant to 40 CFR Part 61, National Emission Standards for Hazardous Air Pollutants (NESHAPS).

C. EXCEPTIONS

1. Procedure -- Analysis of site-specific conditions.

2. Applicability -- Where health and safety would be endangered, or where cost clearly outweighs benefits.

D. CRITERIA SOURCE

Criteria	Source
Residual Contamination Criteria[1/]	
Soil Criteria	DOE Order 5480.1A, 40 CFR Part 192[2/]
Structure Criteria	40 CFR Part 192, proposed ANSI N13.12.
Control of Radioactive Wastes and Residues	
Interim Storage Long-Term Management	DOE Order 5480.1A 40 CFR Part 192

Exceptions

Procedure	40 CFR Part 192
Applicability	40 CFR Part 192

1/ The bases of the residual contamination criteria are developed in ORO-831 as supplemented and ORO-832.

2/ Based on limiting the concentration of radon-222 decay products to 0.03 WL within structures.